Exergame Design for Elderly Users: The Case Study of SilverBalance

Kathrin Maria Gerling, Jonas Schild, Maic Masuch
Entertainment Computing Group
University of Duisburg-Essen
Forsthausweg 2
47057 Duisburg, Germany
+49 203 379 1150
{kathrin.gerling, jonas.schild, maic.masuch}@uni-due.de

ABSTRACT
In this paper, we discuss chances and challenges of game design for an elderly audience with a focus on the development of safe and usable exertion games for frail senior citizens. Based on an analysis of theoretical constraints, we conducted a case study which implements different balance tasks for elderly players featuring the Nintendo Wii Balance Board which encourages users to actively engage in game play. Furthermore, we tested the feasibility of the board as input device for our case study SilverBalance. Our results indicate that age-related impairments influence the use of video games among frail elderly in many respects, hence their needs have to be considered during the design process. In this context, our paper provides a foundation for future research regarding digital games for the elderly.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Ergonomics, Input devices and strategies*; K.4.2 [**Computers and Society**]: Social Issues – *Assistive technologies for people with disabilities, Handicapped persons/special needs*; K.8.0 [**Personal Computing**]: General – *Game*.

General Terms
Measurement, Design, Human Factors, Experimentation.

Keywords
Assistive Technologies, Exergaming, Game Design, Elderly, Silver Gaming, Safety, Usability, Game Interface Design.

1. INTRODUCTION
During the past decades, digital games have been a popular leisure activity among children, teenagers and young adults. However, with the availability of new consoles aimed at casual gamers, different target audiences have been addressed.

ACE '10, 17-NOV-2010, Taipei, Taiwan

Since the introduction of the Nintendo Wii and DS consoles, the amount of "wellness gamers" engaging in mentally or physically challenging games has vastly increased with a large percentage of players in their forties and fifties [7]. Additionally, the Wii console is becoming a more and more popular leisure activity for elderly people. Research results suggest that the console is widely accepted among senior citizens [24] and that playing Wii games has a positive impact on the overall well-being of institutionalized elderly [12, 25]. Furthermore, physically engaging games may reduce the risk of depression among senior citizens [19].

With a growing number of exertion games hitting the market since the Nintendo Wii Balance Board was released, new possibilities in game design for elderly persons evolve. Although most games (e.g. Wii Fit, Skate It or Vertigo) were developed for a young audience, preliminary research results suggest that games like Wii Fit may be used to improve balance, gait and reduce the risk of falls in a therapeutic context [18]. However, only a few mini games and exercises are fully accessible to elderly players [18]. In the context of this paper, we examine the suitability of exergames for senior citizens with a focus on age-related changes. Furthermore, we investigate the promising opportunity of designing exertion games for an elderly audience based on the Balance Board and present our game prototype SilverBalance.

2. SYSTEMS FOR ELDERLY GAMERS
While several studies of psychological effects of digital games on senior citizens are available, only few researchers have developed entertainment systems which particularly address the issue of digital game design for an elderly audience with a focus on physical exertion.

Generally, a variety of augmented or mixed-reality games aimed at an elderly audience has been created. Khoo et al. [14] designed Age Invaders, an adapted version of the original Space Invaders game. It accounts for age-related sensomotor deficits by offering different player roles and by engaging both younger and older players in the game. The augmented dancing environment DanceAlong projects footsteps on the floor while showing videos of dancing scenes taken from popular movies [13]. It is hoped to foster dancing activities and social engagement among elderly. Furthermore, digital tabletop games have been designed to meet the needs of an elderly audience. Mahmud et al. [15] found that senior citizens primarily enjoy simple card games such as poker and designed a tabletop game in which players have to draw cards in order to move checkers on a projected grid. ElderGames [9] is

a table-based digital game for elderly users that combines game elements with cognitive challenges and sensomotor training. Rehabilitation systems such as the commercially available SilverFit [22] have been designed to encourage physical activity and support virtual geriatric rehabilitation. Burke et al. created serious games aimed at the support of an independent domestic rehabilitation process of stroke patients. Such mixed-reality applications may positively influence the motivation of patients to engage in therapy, which is crucial for a quick recovery [4].

In summary, all these approaches indicate a huge potential for game-based systems specially designed for an elderly audience. Despite, the use of custom technology makes it difficult to apply and compare such games to existing commercial systems. As a result, large parts of the elderly population are unable to benefit from recent developments. This issue has merely been addressed by the design of the senior-friendly poker game TableTalk Poker [21]. Hence, this paper addresses this issue by examining a design concept aimed at senior citizens that includes a commercially available mass market input device.

3. DESIGNING EXERTION GAMES FOR ELDERLY USERS

Game design for elderly challenges best practices and design guidelines in many respects: The target audience includes sportive people in their late fifties, seniors with impairments who are still able to lead an independent life as well as frail elderly living in nursing homes. This heterogenous nature has to be accounted for when designing digital games and interaction paradigms [2, 5].

3.1 Age-Related Changes and Requirements

In order to design an enjoyable and safe gaming experience for elderly users, several age-related requirements need to be considered. From a psycho-physiological perspective, aging affects the quality of life on various levels:

- Cognitive impairments (e.g. decrements in episodic memory, variances in working memory performance) affect problem solving skills and information processing [1, 9]. Elderly persons often suffer from a reduced attention span when working on complex tasks [1, 6].
- A decline of existing motor skills includes decrements in fine motor skills and changes in posture and balance [1]. Motor learning of new skills is also negatively affected by age [1, 6]. Physical impairments include decrements in sensory processes which affect the interaction with the environment [9].
- Chronic illnesses ranging from arthritis to severe heart conditions have an impact on the physical abilities and mobility of senior citizens [6].

However, not all elderly persons experience the full range of the aforementioned impairments, yet frail elderly persons living in full-care nursing homes are most likely to be severely influenced by age-related impairments [6].

Particularly concerning the use of video games, the impact of age has been examined by Weisman [26] and Whitcomb [27] in the 1980s and 90s. They propose several game design recommendations including adjustable game speed and difficulty as well as the design of accessible interfaces. 25 years later, Ijsselsteijn et al. [11] also examine digital games and emphasize on impairments in visual and auditory perception and a loss of sensomotor skills. They suggest visually adjustable games (e.g. regarding the size of fonts and windows, colors and contrast) which deliver multimodal feedback and do not rely on one communication channel only. Flores et al. [8] extend this approach and recommend the design of appropriate cognitive challenges, a simple user interface and motivational feedback. Additionally, they recommend the implementation of social activities and the creation of meaningful play through learning objectives based on research results which suggest that elderly players have a preference for simplistic puzzle and quiz games [9, 20]. Finally, they developed criteria for the development of games for stroke rehabilitation which recommend that games should adapt to different motor skill levels and feature therapy-appropriate requirements regarding the patient's range-of-motion [8]. Based on findings from the ElderGames project, usability criteria for technologies for the elderly were compiled [9]. They include the reduction of steps necessary to complete tasks to reduce the cognitive load, the availability of immediate feedback and the adaption of systems to the users' goals.

Besides cognitive and physical challenges, a large part of today's elderly has limited experiences using digital games, which is associated with a generally lower level of computer literacy [3, 6] and the late adoption of new technologies [5]. This results in poor domain knowledge and a higher access barrier when approaching gaming systems [11, 17].

3.2 Design Criteria for Exertion Games

While various design challenges for the design of exertion games aimed at a younger audience have been addressed (cf. [16, 23]), research has not included the needs of frail elderly players.

Based on age-related needs and requirements described in the previous section, we identified four major guidelines which should be applied when designing exertion games for the elderly using the Nintendo Wii Balance Board or similar devices.

- Interaction mechanisms should allow for navigation while sitting or standing. Thus, the player can choose an adequate interaction scenario. In addition to foot-based input, using the player's hands and arms may be appropriate to reduce access barriers for persons using wheelchairs.
- Extensive or sudden movements should be avoided. Additionally, the player may not be asked to lean backwards in order to trigger certain in-game actions to take age-related physical limitations such as decrements in posture and balance into account.
- Elderly players should be given the possibility of individually adjusting the level of difficulty, game speed and the sensitivity of the input device. Thereby, challenging experiences for broad audiences equally account for individual needs.
- Due to the target audience's lack of previous gaming experience, games should focus on simple interaction mechanisms and provide the player with constructive criticism to avoid frustration and foster an enjoyable player experience.

Paired with the design considerations described within section 3.1, we believe that the application of these guidelines will improve the suitability of exertion games for senior citizens. In order to

verify this assumption, we created the game prototype SilverBalance, which was designed for an elderly audience.

4. SILVER BALANCE

SilverBalance is an exertion game prototype that consists of two balance tasks which both involve the Balance Board. It offers simple and intuitive interaction paradigms and does not require extensive parallel user actions. We intend to use SilverBalance specifically as a tool for the analysis of further requirements of an elderly audience within later evaluations. The core game mechanic behind SilverBalance is the placement of different obstacles within the game area, which require specific player reactions in order to avoid collisions with the player's virtual representation (cf. fig. 1).

SilverBalance supports navigation in two positions: (1) sitting in an upright position with the player's feet placed on the board; and (2) standing on the board as required for most commercial Balance Board games. This allows exertion play by users with different levels of bodily and cognitive impairments. Furthermore, threshold values adjusting the board sensitivity may be altered according to the player's needs and the simplistic design of the user interface accounts for reduced visual and cognitive abilities.

4.1 SilverBalance Tasks

The first balance task features obstacles which are randomly aligned to the right or left side of the game area and slowly approach the bottom of the screen after entering it from the top. The player is represented by the red square which can be moved by shifting weight to the left or right side of the Balance Board. The goal of the sample is to avoid falling obstacles as long as possible while their speed is increased after each turn. Thus, the sample has no definite ending but is limited by the player's abilities to react to the development of game play, which offers the possibility of examining high scores of different target audiences during the evaluation phase.

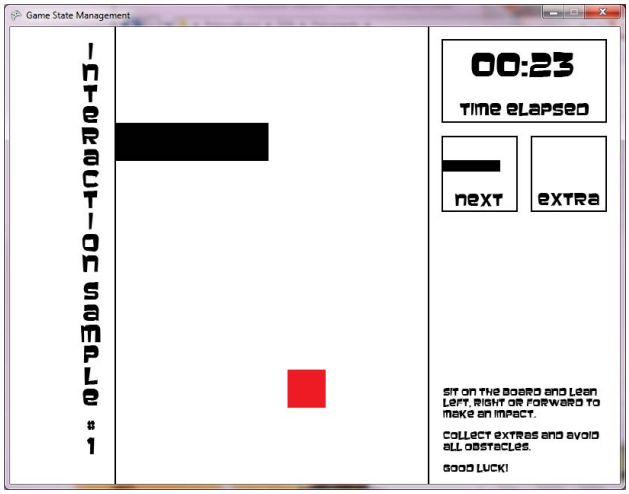

Figure 1: Graphical design of SilverBalance.

The second balance task introduces obstacles which cover the whole width of the screen and differ in length. In order to avoid possible collisions, the player is asked to put pressure on the top half of the Balance Board. Thereby, a 'jumping' state is reached which has to be held by executing constant pressure on the board until there is no contact between the player's representation and the corresponding obstacle. Because the weight shift implemented within this task is similar to the movement which is required when getting up from a chair, we expect an intuitive transition between the regular as well as the 'jumping' game state. As with balance task #1, speed is increased during game play until the user is no longer able to avoid collisions. Finally, at the end of each task the player is provided with feedback regarding his or her performance and high scores are saved to be displayed to returning users.

5. FOCUS GROUP TEST

In order to evaluate the results of our implementation, we conducted a focus group test which included both SilverBalance tasks. The test took place at a nursing home of the HEWAG group located in Duisburg, Germany, where nine senior citizens averagely aged 84 (range 77 to 91) were asked to play the prototype. During these gaming sessions, we made several observations which may be beneficial for future approaches towards exergame design for elderly persons. Generally speaking, all of the participants were able to interact with the balance tasks adequately (average obstacle score for Balance Task #1: 12, Balance Task #2: 10) and stated that the minimalistic design allowed them to focus on the game more easily. In this context, offering the possibility of engaging in play while being seated was advantageous as all group members were dependent on assistive devices while walking or standing and did not feel confident enough to remain standing for a longer period of time. Additionally, being able to play the game while being seated allowed persons sitting in wheelchairs to participate in the game. Furthermore, we observed that the group quickly engaged in competitive play by comparing and commenting on other player's results despite the simplistic graphical design and game mechanics of the prototype. The focus group test also revealed problematic areas such as the negative impact of diseases and impairments (e.g. stiffness in joints and attention deficits) after a longer period of playing. Hence, it seems appropriate to include alternative interaction paradigms in future game designs. Additionally, the current design does not account for the player's long term motivation and should be extended with regards to this issue. However, this may be challenging due to the fact that a more complex game design has to be combined with accessible and ideally scalable interaction paradigms.

6. CONCLUSION AND FUTURE WORK

The development of SilverBalance and a first focus group test have shown that the application of design guidelines for exertion games presented within this paper contributes to the development of accessible video games for senior citizens. Furthermore, the implementation of different ways to use the Balance Board (e.g. either standing or sitting) presents a more accessible design opportunity for elderly players. Additionally, the adherence to general design guidelines when designing digital games for elderly contributed to the creation of the interface design.

The summary of design criteria for elderly presented within chapter 3.1 shows that many guidelines strongly focus on interaction design. However, games are complex systems which are likely to be affected by age-related changes and impairments on various levels. Therefore, further research with a focus on the impact of age on different structural elements of games should be carried out. Future work includes the full evaluation of

SilverBalance and merging the tasks included in the prototype and design guidelines presented within this paper into a complete game design. The iterative and user-centered design process will be accompanied by nursing staff and a group of elderly persons. On a final note, all of the elderly participants of the evaluation were eager to participate in weekly gaming sessions. This strongly suggests that senior citizens are open to new technologies, which offers new possibilities for game design.

7. ACKNOWLEDGMENTS

We would like to thank the participants of the focus group for their contribution to our research. Furthermore, we would like to thank the HEWAG nursing home Duisburg-Neudorf.

8. REFERENCES

[1] J. E. Birren and K. W. Schaie. *Handbook of the Psychology of Aging*. San Diego, CA, USA: Academic Press, 2001.

[2] M. Blythe, A. Monk, and K. Doughty. Socially dependable design: The challenge of ageing populations for HCI. *Interacting with Computers*, 17(6), 672-689, 2005.

[3] D. C. Burdick and S. Kwon. *Gerotechnology: research and practice in technology and aging*. New York: Springer Publishing Company, 2004.

[4] J. W. Burke, M. D. J. McNeill, D. K. Charles, P. J. Morrow, J.H. Crosbie, and S.M. McDonough. Optimising engagement for stroke rehabilitation using serious games. In: *The Visual Computer: International Journal of Computer Graphics.* Serious Games and Virtual Worlds, 1085-1099, 2009.

[5] S. J. Cutler. Technological Change and Aging. In R. H. Binstock and L. K. George, *Handbook of Aging and the Social Sciences*. Burlington, USA: Academic Press, 2006.

[6] S. J. Czaja and C. C. Lee. Information Technology and Older Adults. In *The Human Computer Interaction Handbook*, A. Sears and J. A. Jacko, Eds. New York, New York, USA: Lawrence Erlbaum Associates, 2008.

[7] Entertainment Software Association of Canada. *Essential Facts about the Canadian Computer and Video Game Industry*, 2009. Available at http://www.theesa.ca/documents/EssentialFacts2009EN.pdf, last access: 07.07.2010.

[8] E. Flores, G. Tobon, E. Cavallaro, F. I. Cavallaro, J. C. Perry, and T. Keller. Improving patient motivation in game development for motor deficit rehabilitation. *Proceedings of the 2008 International Conference on Advances in Computer Entertainment Technology*, Yokohama, Japan, 2008.

[9] L. Gamberini, M. Alcaniz, G. Barresi, M Fabregat, F. Ibanez, and L. Prontu. Cognition, technology and games for the elderly: An introduction to ELDERGAMES Project. *PsychNology Journal*, 4(3): 285-308, 2006.

[10] M. Griffith. The Therapeutic Value of Video Games. In *Handbook of Computer Game Studies,* J. Raessens and J. Goldstein, Eds. Cambridge: MIT Press, 2005.

[11] W. Ijsselsteijn, H. H. Nap, and Y. de Kort. Digital Game Design for Elderly Users. *Proceedings of FuturePlay 2007*, Toronto, Canada, 2007.

[12] Y. Jung, K. J. Li, N.S. Janissa, W. L. C. Gladys, and K. M. Lee. Games for a Better Life: Effects of Playing Wii Games on the Well-Being of Seniors in a Long-Term Care Facility. *Proceedings of the Sixth Australasian Conference on Interactive Entertainment*, Sydney, Australia, 2007.

[13] P. Keyani, G. Hsieh, B. Mutlu, M. Easterday, and J. Forlizzi. DanceAlong : Supporting Positive Social Exchange and Exercise for the Elderly Through Dance. *Proceedings of CHI 2005*, Portland, USA, 2005.

[14] E. T. Khoo, S. P. Lee, and A. D. Cheok. Age invaders. *Proceedings of the International Conference on Augmented Tele-Existence*, Christchurch, New Zealand, 2005.

[15] A. A. Mahmud, O. Mubin, S. Shahid, and J. Martens. Designing and evaluating the tabletop game experience for senior citizens. *Proceedings of NordiCHI '08*, Sweden, 2008.

[16] F. Mueller and S. Agamanolis. Exertion Interfaces. *Proceedings of the 26th annual SIGCHI Conference on Human Factors in Computing Systems*, Florence, Italy, 2008.

[17] H. H. Nap, W. A. Ijsselsteijn, and Y. A. W. de Kort. Age Differences in Associations with Digital Gaming. *Proceedings of DiGRA 2009*, London, UK, 2009.

[18] T. Pigford. Feasibility and Benefit of Using the Nintendo Wii Fit for Balance Rehabilitation in an Elderly Patient Experiencing Recurrent Falls. *Journal of Student Physical Therapy Research*, 2(1): 12-20, 2010.

[19] D. Rosenberg, C. A. Depp, I. V. Vahia, J. Reichstadt, B. W. Palmer, J. Kerr, G. Norman, and D. V. Jeste. Exergames for Subsyndromal Depression in Older Adults: A Pilot Study of a Novel Intervention. *American Journal of Geriatric Psychiatry*, 18(3), 221-226, 2010.

[20] B. De Schutter and V. Van Den Abeele. Meaningful Play in Elderly Life. *Proceedings of the 58th Annual Conference of the ICA*, Montreal, Canada, 2008.

[21] N. Shim, R. Baecker, J. Birnholtz, and K. Moffatt. TableTalk Poker: An Online Social Gaming Environment for Seniors. *Proceedings of FuturePlay 2010*, Vancouver, Canada, 2010.

[22] SilverFit BV. *SilverFit Virtual Rehabilitation System*, 2010. Available at http://www.silverfit.nl/, last access: 07.06.2010.

[23] J. Sinclair, P. Hingston, and M. Masek. Considerations for the design of exergames. *Proceedings of the 5th International Conference on Computer Graphics and Interactive Techniques*, Perth, Australia, 2007.

[24] Y. Theng, A. B. Dahlan, M. L. Akmal, and T. Z. Myint. An exploratory study on senior citizens' perceptions of the Nintendo Wii. *Proceedings of the 3rd International Convention on Rehabilitation Engineering & Assistive Technology*, Singapore, 2009.

[25] G. Ulbrecht, D. Wagner, and E. Gräßel. *Pilotstudie zur möglichen Wirksamkeit von Sportspielen an der Wii-Konsole bei Pflegeheimbewohnerinnen und –bewohnern*, 2010. Available at http://diakonie-bayern.de/uploads/media/Wii_Forschungsbericht_Kurzfassung_01.pdf, last access: 08.06.2010.

[26] S. Weisman. Computer Games for the Frail Elderly. In: *Gerontologist*, 23(4): 361-363, 1983.

[27] G. R. Whitcomb. Computer games for the elderly. *ACM SIGCAS Computers and Society*, 20(3), 112-115, 1990.